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DELAWARE'S CHANGING SHORELINE

KENT COUNTY AND NORTHEAST SUSSEX COUNTY

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Delaware State Planning Office

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Kent County and Northeast Sussex County

Introduction

The Delaware shoreline, both of Delaware Bay and the Atlantic Ocean, is an unstable, ever-changing environment subject to the conflicting natural processes of deposition on the one hand and erosion and submergence or transgression on the other hand. The first process increases the landward side of the shoreline and the latter processes decrease the landside. In a natural state, without human interference, the shoreline is constantly shifting, moving inland here and seaward there, but in large scale terms of the entire Delaware coastline over a very long period of time the sea has advanced at the expense of the land. This slow but steady advance of the sea goes on today and is expected to continue for the foreseeable geologic future.

The purpose of this publication is to describe, in non-technical terms, the nature of the physical forces of the sea acting upon the shoreline, the effects of mans' devices upon these forces and the resulting configuration of Delaware's Bay and Ocean shoreline. Some specific questions this publication attempts to answer are:

What are the forces of erosion and deposition that cause some beaches to diminish and others to grow?

What are the shoreline geomorphological and geological features that are acted upon and shaped by these forces?

What are the consequences to mans' use of the shoreline and coastal area of these physical forces and processes?

What is the geological history of changes in Delaware's shoreline and what is the probable (foreseeable) geological future?

What actions has man taken to reduce or re-direct the natural processes of shoreline change and what are the results of these actions?

How can man work with nature so that over generations of time he may safely and productively use the shoreline and coastal resources without irreparably damaging or destroying them?

To answer these questions, the State Planning Office commissioned the Department of Geology, University of Delaware, to study the Delaware shoreline. This paper summarizes the findings of that study and includes some supplementary material from other sources. General principles of processes of shoreline change and of mans' measures to control those processes are described, followed by a description of the coastal features and shoreline changes from the Smyrna River to Broadkill Beach; Indian River Inlet to Fenwick Island.

General Principles

The basic natural process occurring over a long period of time and along the entire Delaware coast is the advance of the sea over the land, that is, a rise of sea level with respect to the land surface called transgression. Figure 1 illustrates this advance of the sea over the past 12,000 years and the coming 75,000 years.

Three geologic processes cause this transgression. The first is the actual rise of sea level. During the Pleistocene age until about 15,000 years ago much of the Northern Hemisphere was covered by ice caps that advanced and retreated over thousands of years as the earth's climate cooled or warmed. Since the retreat of the last great ice cap until now the sea is believed to have risen by about 440 feet. Evidence along the Delaware coast indicates that this rise of sea level is continuing. The second geologic process causing the sea level rise is the compaction of sediments in the earth's crust causing the sea floor and nearshore land surfaces to sink. The third process is that of movements of the earth's crust called the tectonic effect.

Although sea level rise is a continuing long term process it has been very irregular over the centuries. In some periods it may rise dramatically while in others it may be slight or even temporarily cease. Before 5,000 years ago sea levels rose at rates of more than one foot per century along the Delaware coast; over the last 2,000 years it has risen at a rate of less than one-half that rate (0.41') per century.

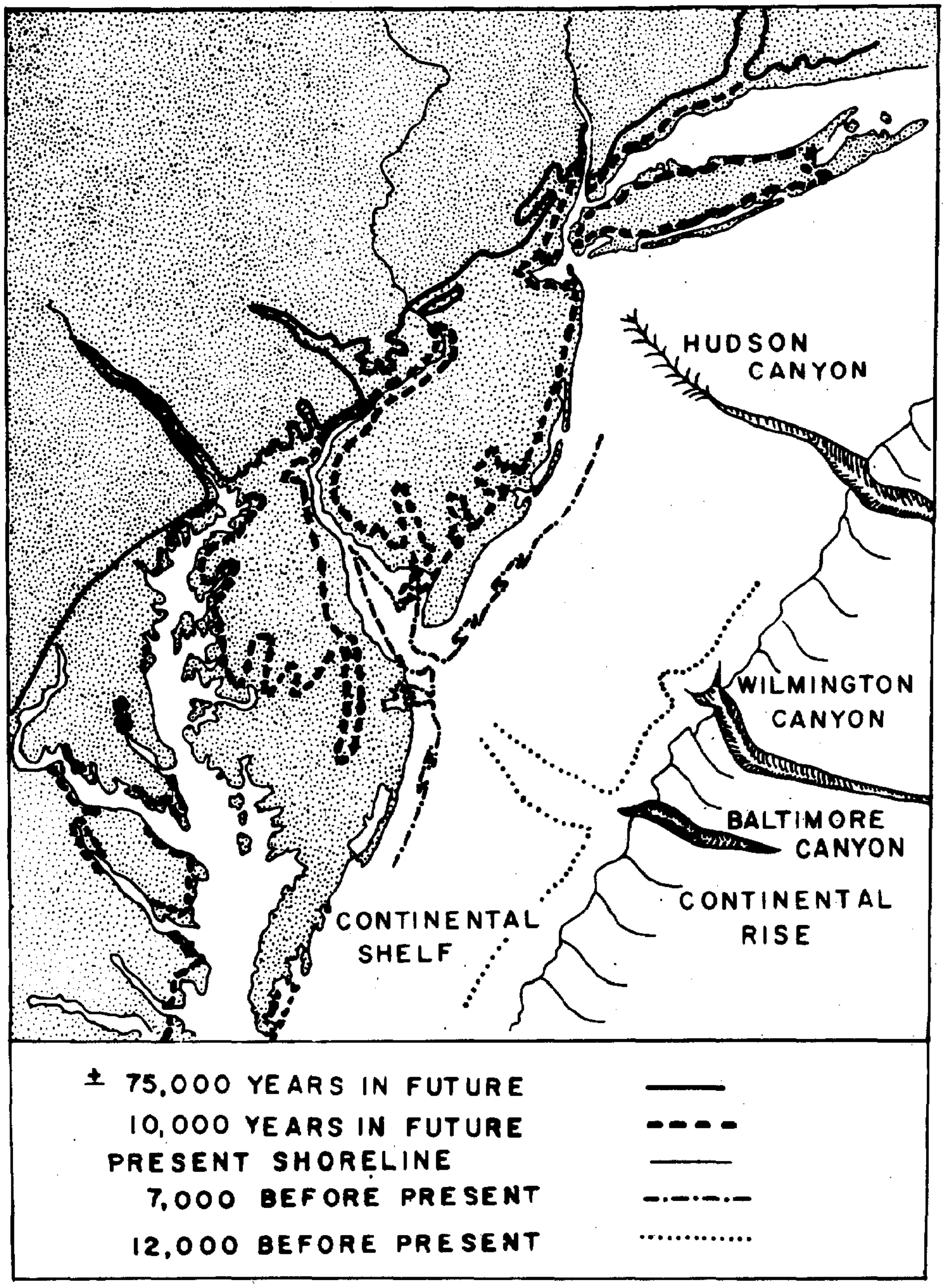
When sea level changes have been plotted for an area, local effects such as compaction of sediments can then be determined. For example, at South Bowers the surface may be subsiding at about one-half foot per century in addition to being subjected to a sea level rise of about one-half foot per century. On the older, firmer Pleistocene upland just north of the Murderkill River at Bowers compaction is not significant. Thus, building at South Bowers is a more hazardous enterprise than it is at Bowers just a few hundred feet away. At South Bowers in the past a one foot rise of the sea level has resulted in up to 700 feet of landward erosion; demonstrating that one foot per century is significant indeed to mans' use of the South Bower's shoreline.

The rise of sea level has a marked effect on Delaware's barrier beaches as shown in Figure 2. As the sea rises its waves attack the beach at a higher elevation. The resulting increased coastal erosion and dune movement caused by blowing sands results in a slow but steady landward and upward movement of the shoreline. That is, the relative positions of dunes and beaches remain the same, but the entire coastal system is moved landward.

In addition to the process of transgression (relative sea level rise) two other geologic processes affect coastal change. These processes are littoral transport and coastal washover.

Littoral transport is the movement by waves and currents of sediments near the shore both parallel to shore (longshore transport) and perpendicular to shore (onshore-offshore transport). Sediment movement is a continuous and

FIGURE 1



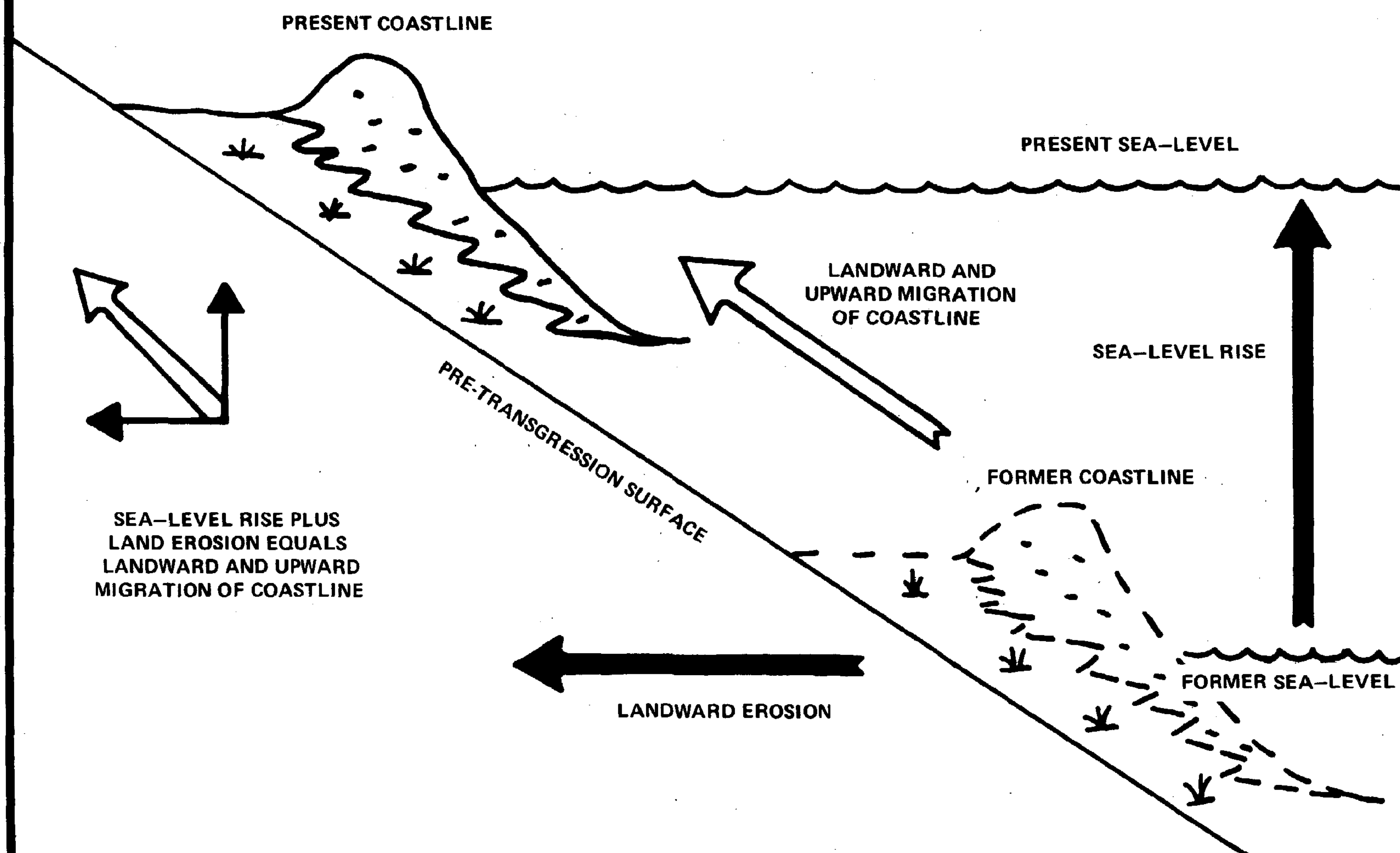
PALEOGEOGRAPHY OF DELAWARE'S SHORELINE DURING THE HOLOCENE EPOCH OF THE LAST 12,000 YEARS AND TENTATIVELY PROJECTED INTO FUTURE INTERGLACIAL AND NONGLACIAL CONDITIONS.

Source: The Coastal Zone of Delaware, The Final Report of the Governor's Task Force on Marine and Coastal Affairs, 1972.

FIGURE 2

THE BRUNN THEORY

OF SEA–LEVEL RISE AS A CAUSE OF COASTAL EROSION



cyclical process varying in time and place. A single storm can remove as much sediment as several months or even years of normal movement.

Understanding of littoral transport requires some knowledge of wave characteristics. Waves are generated by disturbances of the sea surface. Undersea earthquakes, volcanic eruptions and submarine landslides can cause waves, but usually the cause is the friction effect of winds over the ocean surface. Wave dimensions are caused by wind velocity, duration of time the wind flows, the distance it blows across the water (the fetch) and the distance the wave travels after it is generated by the wind. The stronger is the wind, the longer the wind blows and the longer the fetch the larger the waves will be.

In southern Delaware Bay (at Lewes) prevailing winds are from the southwest, but northeast, north and south winds occur nearly as often. Winds of gale force (30 miles per hour or higher) occur most frequently from the northwest; highest velocity winds are most often from the northeast.[1] (pg. x.6, Appendix X, Charles T. Main report).

Wave terminology includes:

1) the crest - the highest part of a wave

2) the trough - the lowest part of a wave

3) wave height - the vertical distance between a crest and the preceding trough

4) wave length - the horizontal distance between two adjacent wave crests

5) the wave period - the time for two successive wave crests to pass a given point

As waves approach the shore moving into shallower water, the bottom affects wave motion in several ways:

1) wave velocity decreases

2) wave length decreases as velocity decreases

3) wave height first decreases, then increases just before the wave breaks on the shore

4) wave steepness increases with the increase of wave height and decrease of wave length

Wave refraction is a characteristic important to the understanding of erosional effects of waves on a shoreline. In shallow water when a wave crest

[1]Charles T. Main, Inc., Recreation Potential: State of Delaware Interim Report, Appendix X, p. x.6.

moves at an angle to bottom contours segments of the wave front travel in different water depths, thus at different speeds. The variation in speed causes the wave crest to bend into alignment with the bottom contours. This bending effect is refraction. Figure 3 illustrates wave refraction on four different types of shoreline. The orthogonals shown are simply trajectories of selected points along the wave front. Where they converge (Figure 3'b') waves are higher, wave energy is concentrated and there is accelerated erosion; where they diverge (Figure 3 'c') waves are lower, wave energy is dispersed and there tends to be sediment deposition and shoreline accretion (increase). In Figure 3(d) the headland is eroding and the bays are filling-in with sediments eventually resulting in a relatively straight shoreline.

Longshore transport is the littoral movement of sand parallel to the shore. When waves break on the shore at an angle the effect is to move sand-laden water along the shore in a direction related to direction of wave approach and angle of the wave to the shoreline. Figure 4 illustrates longshore transport.

Most shores have net annual longshore transport in one direction. North of Bethany Beach littoral transport along Delaware's Atlantic shore is northward, south of Bethany Beach net transport of sand is southward.

The second component of littoral transport is the onshore-offshore movement of sediment perpendicular to the shoreline. This movement is determined primarily by wave steepness, sediment size and beach slope. In general, high, steep waves will move material offshore, low waves will move it onshore.

Onshore-offshore transport varies with the season. Figure 5 illustrates generalized summer and winter beach profiles associated with onshore-offshore transport processes. Fair weather in summer favors sand accretion on the berm. Stormy winter weather moves sand seaward narrowing the berm and building-up one or two offshore sandbars. Figure 5 is simply a generalized illustration, in actuality winter beach profiles can occur in summer and vice-versa. A berm is simply the flat, above-water features of the beach - what most people think of when referring to "the beach".

Storm wave attacks on beaches increase the onshore-offshore littoral transport of sediments beyond that normally occurring. Figure 6 diagrams storm wave attack on a beach and dune. Profile A shows the beach under normal wave action and the other profiles show it at the various stages of storm wave attack. The destructiveness of storm waves is increased by the storm surge, a rise of water level above normal caused by storm winds that pile the water against the land, raising the water level. Profile D shows the beach after the storm wave attack - the dune and berm have lost much sand, resulting in a landward displacement of both the dune crest and high tide line.

At the waves return to normal the process of berm buildup begins. Long, low waves move sand landward that eventually adds to the berm. The berm grows seaward and resumes its pre-storm profile. Thus, onshore-offshore littoral transport of sand is a continuous, cyclic process.

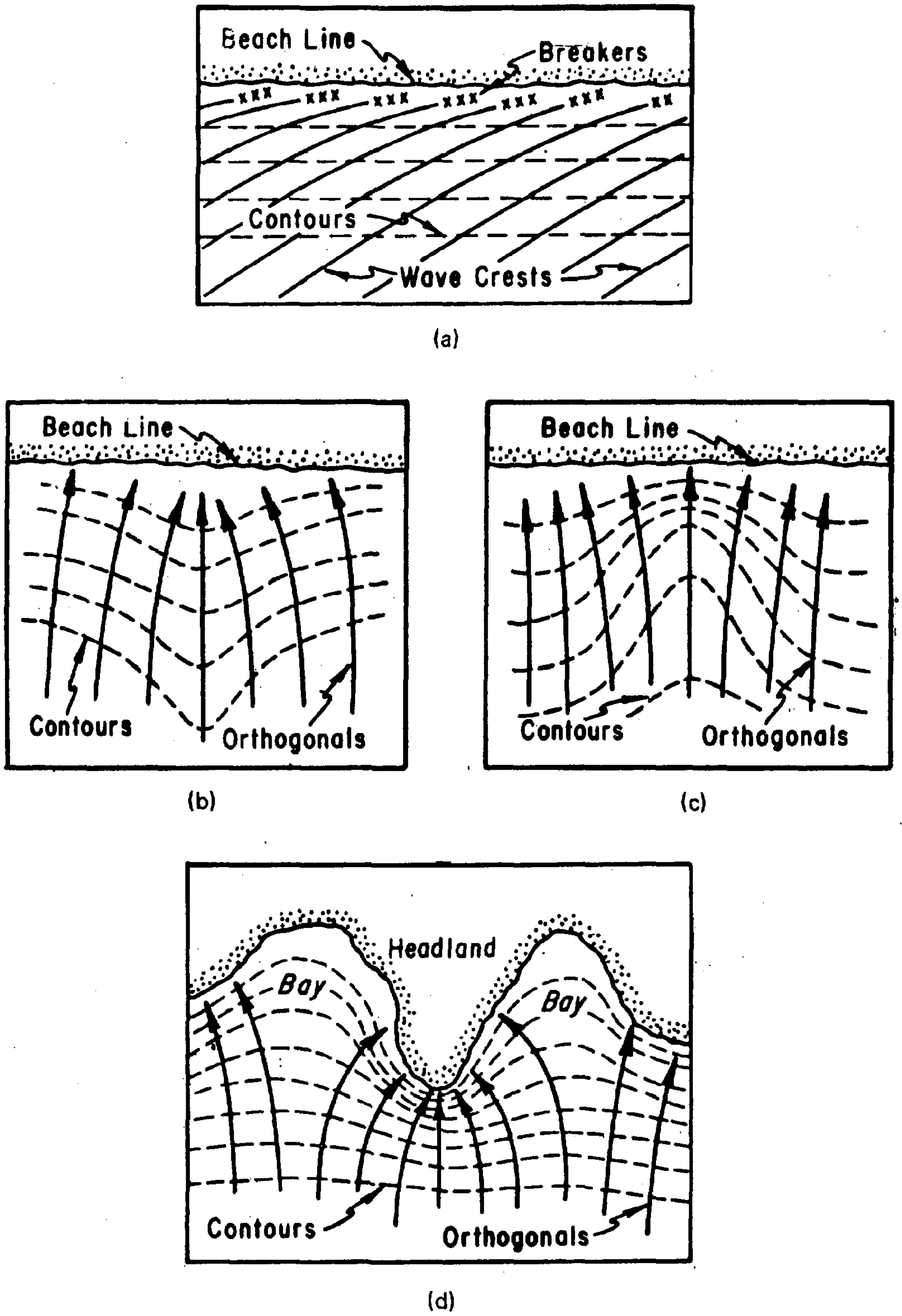


FIGURE 3 Effects of nearshore topography and coastal configuration on wave refraction. (a) Refraction along a straight beach with parallel bottom contours. (b) Refraction by a submarine ridge. (c) Refraction by a submarine canyon. (d) Refraction along an irregular shoreline (from U.S. Army Coastal Engineering Research Center, 1973).

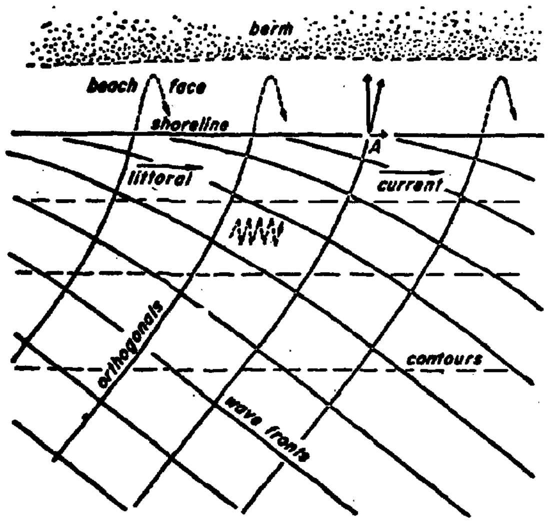


FIGURE 4 Waves approaching a straight shoreline at an angle are not completely refracted. The remaining alongshore component (marked A) is responsible for the littoral current. Paths of sand grains moving to the right with every wave are shown by dotted lines (Bascom, 1964).

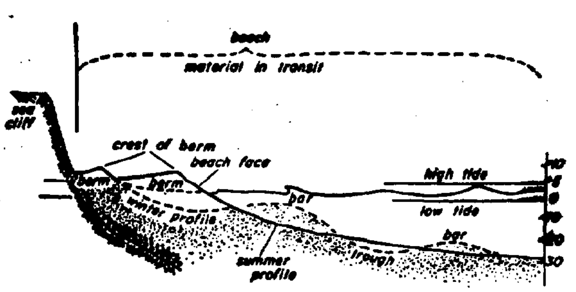


FIGURE 5 Generalized beach profile showing seasonal changes in the distribution of sand (Bascom, 1964). In the summer the beach is wide, with a prominent convex-upward beach face and usually flat, barless submarine profile. In the winter, large waves move sand offshore, producing a narrow berm and one or more submarine bars.

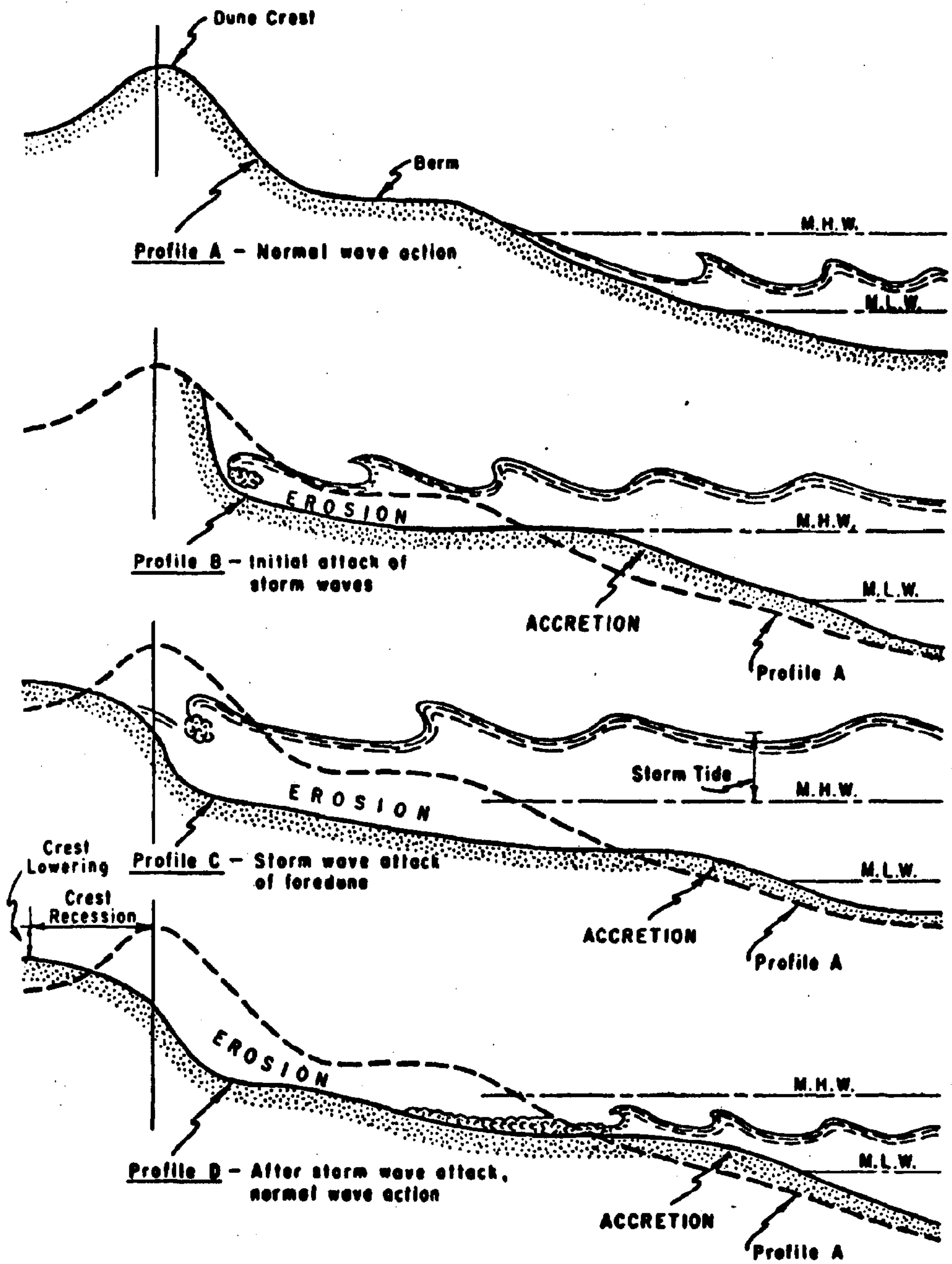


FIGURE 6 Schematic diagram of storm wave attack on beach and dune (U.S. Army Coastal Engineering Research Center, 1973).

The erosional affect of the severe March 1962 storm on Delaware's Atlantic beaches is illustrated in Figure 7. Many miles of beach retreated by 60 to 75 feet.

The "northeaster" of December 1 and 2, 1974, caused extensive shorefront damage. Peak tide levels were nearly as high as in the March 1962 storm but damage was much less because the 1974 storm lasted only through two to three tidal cycles. Along Delaware Bay high tide waters rose through the marshes and the discontinuous beach areas. Washovers were extensive where low dunes offered little protection, as at Broadkill Beach shown in Figure 8.

Washovers are the third process causing coastal change. Storm waves carry sand eroded from the beach, breach the dunes, and deposit large quantities of sand on top of the barrier island and in back-barrier marshes (see Figure 8 above). The result of washover is a landward migration of the shoreline and a building-up of the barrier island.

The washover is a periodic, natural process associated with all barrier islands. It is inevitable that storms will bring future washovers to Delaware's shore; the only questions are when and what the effects will be.

Delaware Bay Past and Future Shoreline Change

During the past century, in general, the Delaware Bay shoreline has undergone continuous erosion averaging from one to twenty-five feet per year. The small areas of accretion are localized, in part caused by mans' activities. Figure 9 shows rates of shoreline erosion and accretion from 1848 to 1972. The average annual rate of erosion during this period was 20 feet. In areas with more compacted sediments, such as the site of Bowers, the average erosion rate was considerably less, a little over four feet between 1843 and 1954 based on Army Corps of Engineers data.

While predictions of rates of coastal erosion on Delaware Bay cannot be precise there will likely be a continuation of recent past history except in the areas where protective devices such as the groins at Broadkill Beach have been built or the few areas growing from natural accretion. While Delaware Bay is partially sheltered from severe storms, its low shoreline, lack of large dunes, and susceptibility to storm tidal surge assure severe erosion during intense storms.

Natural Shore Protection

According to a report of the Army Corps of Engineers Coastal Engineering Research Center man has contributed to the scope of destruction wrought by Atlantic storms by failing to preserve protective features provided by nature.

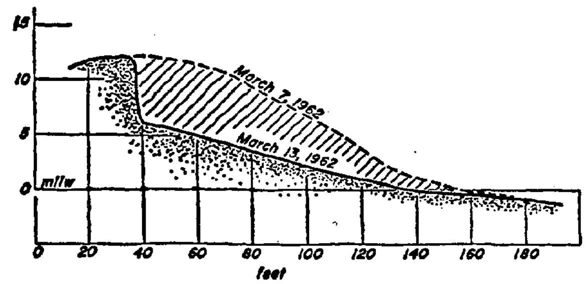


FIGURE 7. Typical erosion pattern of Delaware beaches during the storm of March 1962. Many miles of beach retreated 60 to 75 feet (Corps of Engineers profile in Bascom, 1964).

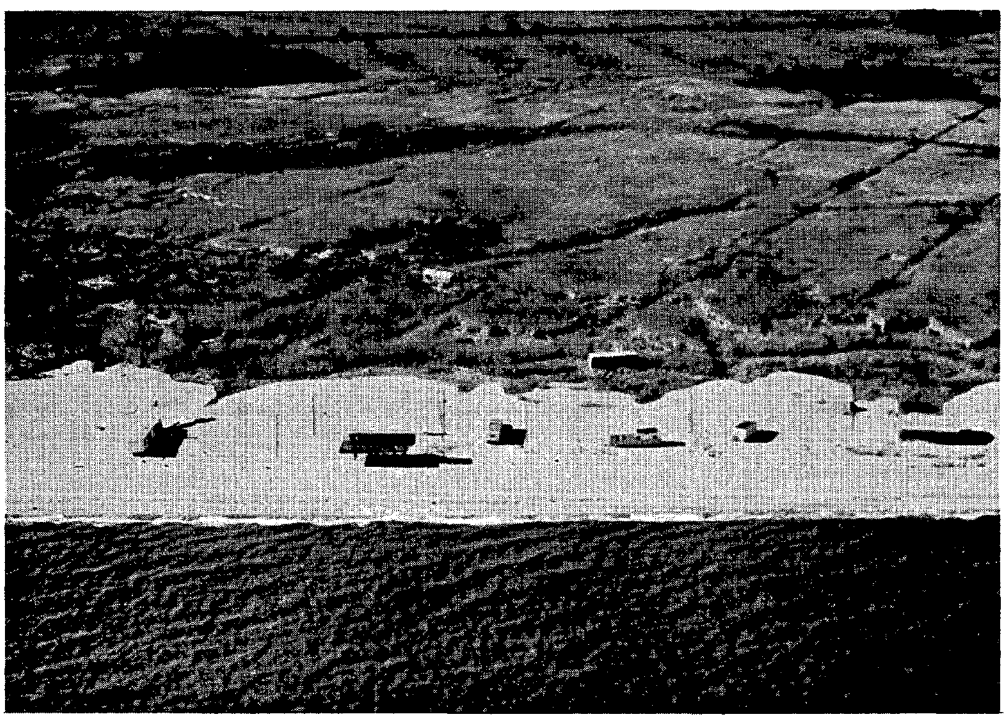
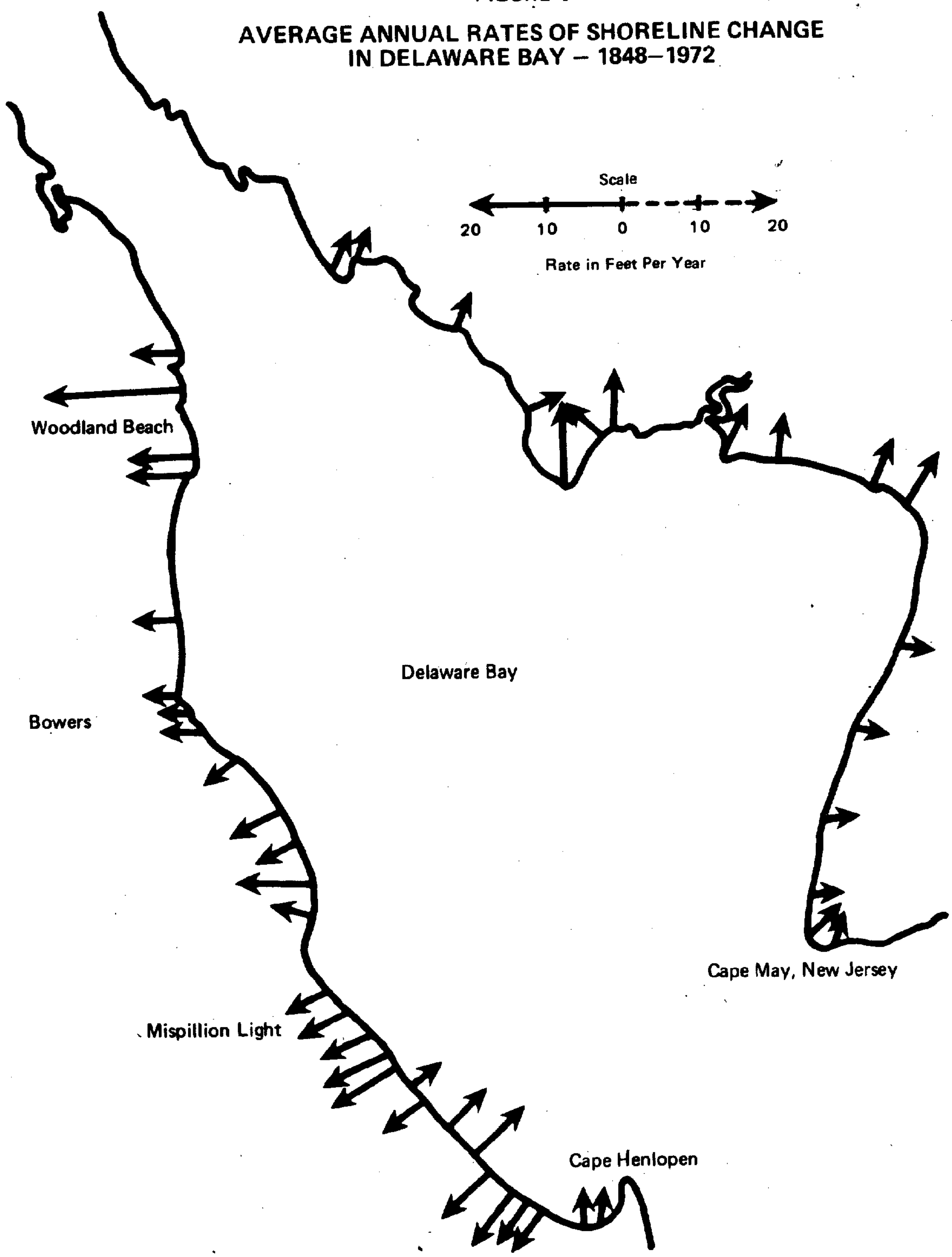


FIGURE 8. Aerial photo of Broadkill Beach area, Delaware Bay, following the December 1974 storm. Breached dunes and washover fans are typical consequences of even mild storms.

FIGURE 9

AVERAGE ANNUAL RATES OF SHORELINE CHANGE IN DELAWARE BAY – 1848–1972



The structure of a beach serves as natural protection against wave action. During normal conditions, the slope of the beach face absorbs most of the wave energy. In times of elevated water levels when waves wash over the berm, coastal sand dunes form an effective barrier to storm waves. Even when breached by severe storms dunes can gradually rebuild themselves provided vegetation can become established on them. Not only are dunes barriers to high waters and onshore winds they also serve the important function of a stockpile of sand to replenish the beach as the dune builds outward and wave action on a high tide carries some of the sand to the foreshore.

Vegetation plays a critical role in the development and maintenance of sand dunes. Grasses and other plants serve to trap overwash and wind blown sand, to dissipate wave energy and to stabilize dunes. This vegetation should be undisturbed by man. Access to beaches should be limited to elevated walkways placed over (not through) dunes at a few locations. The wooden walkways at Cape Henlopen State Park beach are a good example of this principle. The value of dunes and dune vegetation has been recognized in Delaware and a program of dune maintenance and restoration is underway. See Figures 10 and 11 for examples of natural dunes and the State dune stabilization program.

Studies of North Carolina's Outer Banks, a shoreline similar to Delaware's Atlantic coast in many respects, have shown the dynamic ever-changing nature of the shore area and the environmental relationship between coastal dunes and the occasional overwash of ocean waters into lagoons behind the washover barrier beaches and dunes (see Figure 12 for a schematic diagram of shoreline features).

The base level of the berm is determined by the sea and where sand is in short supply, the sea keeps moving the berm back. In such an environment, scattered dunes, dense grasslands and salt marshes represent the natural ecology. If overwash is halted, such lands will be drowned and only a dune line remain. Building a high manmade dune line may lead to future disaster when the sea finally breaks it down. Erosion on the lagoon side will begin and coupled with beach erosion will jeopardize the barrier island.

The studies of the North Carolina shore area concluded that a barrier island - lagoon environment can be harmed by a high barrier dune system, while a structure of a wide berm with scattered dunes of various heights to allow water flow and extensive grasslands and salt marshes is more compatible with natural forces. The wide berm provides resistance to storm waters and supplies sand for natural dune building. Dunes will buildup one behind the other with low areas between the dunes which will serve to slow storm waters. Grasslands behind the dunes will further break wave energy and cause some sand deposition. The sea water will then reach the lagoonal marshes having lost most of its energy and sand load, with little damage beyond flooding. The secret of this structure is flexibility and lack of excessive resistance to natural forces; enough sand is conserved to preserve the barrier island system.

FIGURE 10. Natural dunes and dune vegetation, Lewes Beach.

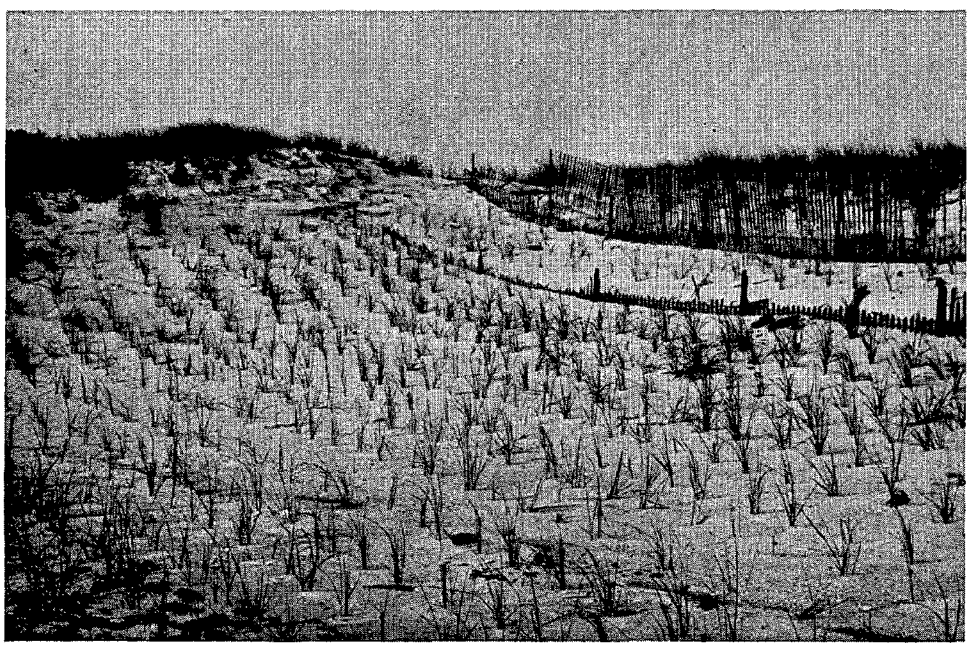


FIGURE 11. Dune maintenance program at Indian River Inlet State Park. Fences and vegetation help stabilize dunes by trapping sand.

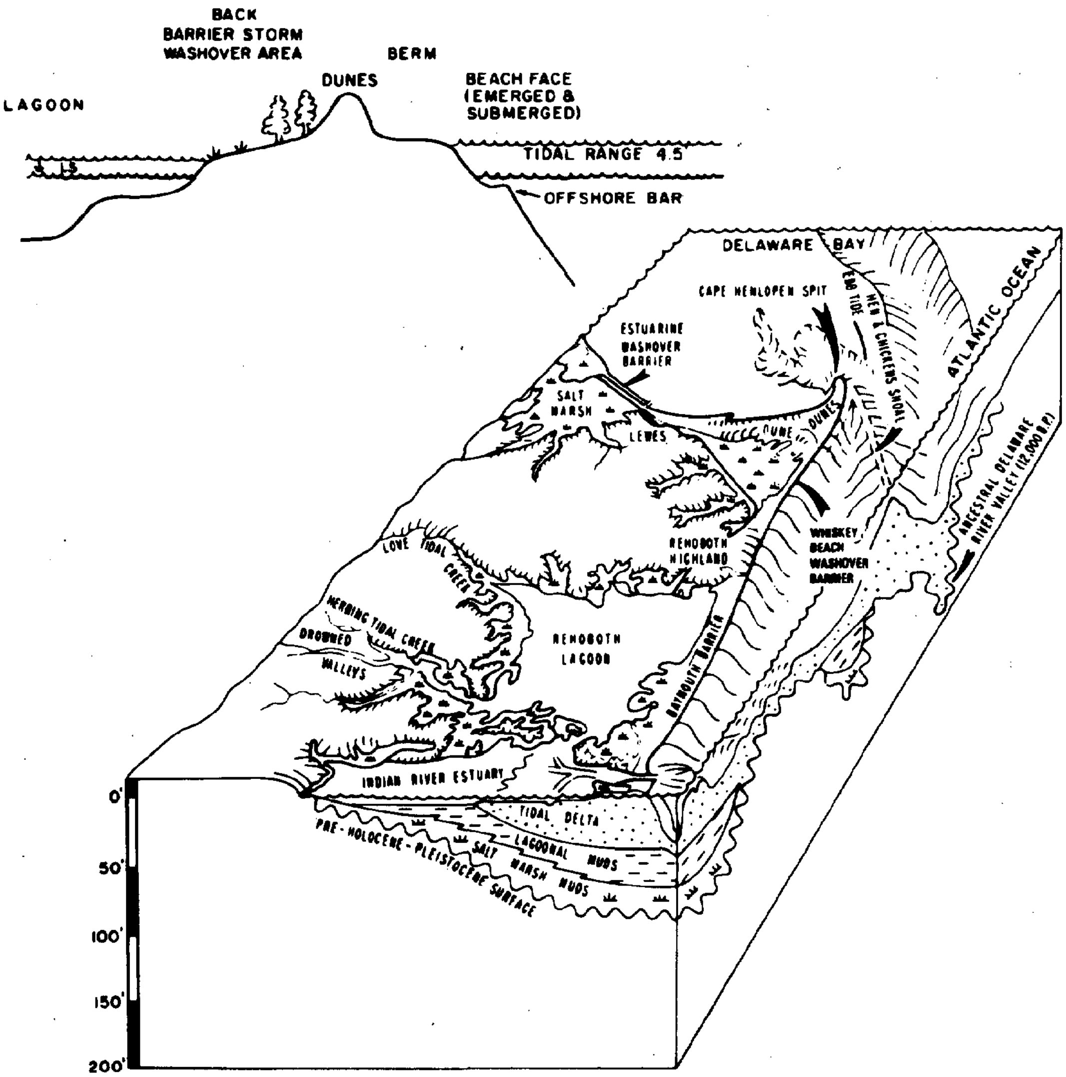


FIGURE 12. TERMINOLOGY USED IN DESCRIBING THE COASTAL ZONE ILLUSTRATED ON A DIAGRAM OF THE GEOMORPHIC ELEMENTS OF DELAWARE'S COASTAL AREA AND THEIR RELATIONSHIPS TO SUBSURFACE GEOLOGIC CROSS SECTIONS OF COASTAL AND NEARSHORE MARINE AREAS.

Source: The Coastal Zone of Delaware, The Final Report of the Governor's Task Force on Marine and Coastal Affairs, 1972, page 93.

Manmade Shore Protection

Shore Protection Devices

In his eagerness to be close to the water, man ignores the fact that land comes and goes, that the sea may reclaim tomorrow the land nature provided in the past. Once seaward limits of a resort are established there is considerable pressure to protect the large investments involved at great cost in terms of storm losses and expenditures for protective measures.

In a natural state and in the early stages of resort development, the beaches and dunes provide adequate storm protection. As development continues the beach is narrowed, the dunes are destroyed or diminished and storm losses increase. To replace the natural defenses against the sea, man has devised a variety of protective measures.

One of the most common protective measures is a bulkhead (see Figure 13). Built of timber, concrete or steel pilings these are a type of wall built approximately parallel to the shoreline to combat erosion. More elaborate variations of bulkheads are solid stone or concrete seawalls and revetments. A revetment has a sloping face of rock or concrete blocks to break the force of waves hitting the seawall. While such devices provide upland protection they do nothing to hold or protect the beach - the greatest asset of shoreline property. In fact, a seawall is detrimental to the beach because the force of waves striking the wall is directed downward, rapidly eroding beach sand.

As a way of retaining beach sand or building-up a beach the groin has been devised. This is simply an obstacle of timber or stone, like a fence or wall, that extends perpendicular to the shoreline across the beach from a dune or bulkhead to a shallow depth in the water. Figure 14 shows a series of groins. The affect on the beach generally is to substantially widen it on one side of the groin and diminish it on the other side. The reason is that the groin traps sand carried in the littoral current increasing beach width on the side facing the direction the littoral current is coming from; the opposite side of the groin is deprived of sand supplied by the littoral current and eroded sand is not replaced by nature. The effect is a jagged, sawtooth-like beach as shown in Figure 14. Since more and more beaches are artificially protected and less and less littoral current sand is available to fill beaches between groins it is frequently necessary to replenish the beaches artificially. Groins should be built only after their affects on adjacent beaches are studied and only if properly designed for the particular site.

Another structure developed to modify or control sand movement is the jetty. Its function is similar to that of the groin, but it differs from groins in being much larger, extending from the shoreline to a water depth equal to channel depth, it is built at inlets to protect navigation openings from shoaling, and it must be high enough to completely obstruct sand movement (whereas most groins allow some sand to flow over the top). While jetties protect channel navigation, they have affects like those of groins by cutting off the longshore supply of sand to the downstream side of the channel. Figure 15 showing the jetties at Indian River Inlet dramatically illustrates the erosional-depositional affects of jetties.

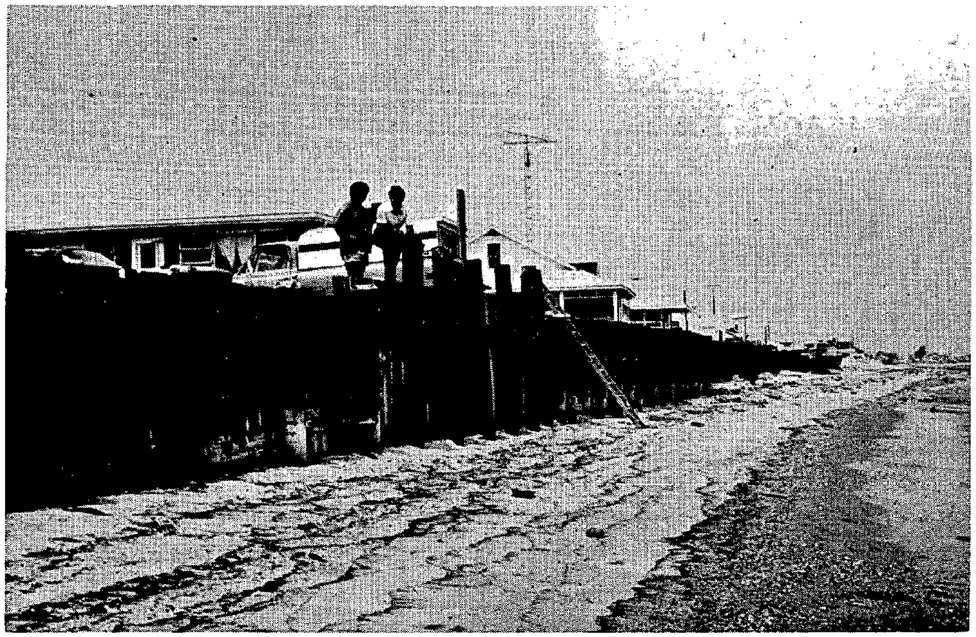


FIGURE 13. Bulkhead at Slaughter Beach, Delaware.

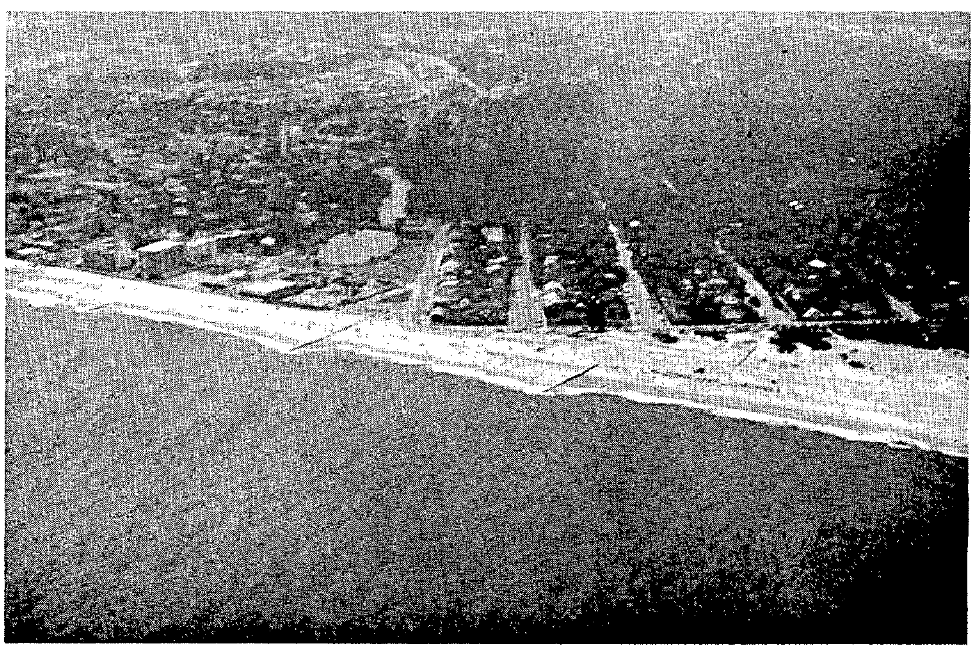


FIGURE 14. Groin field at Rehoboth Beach.

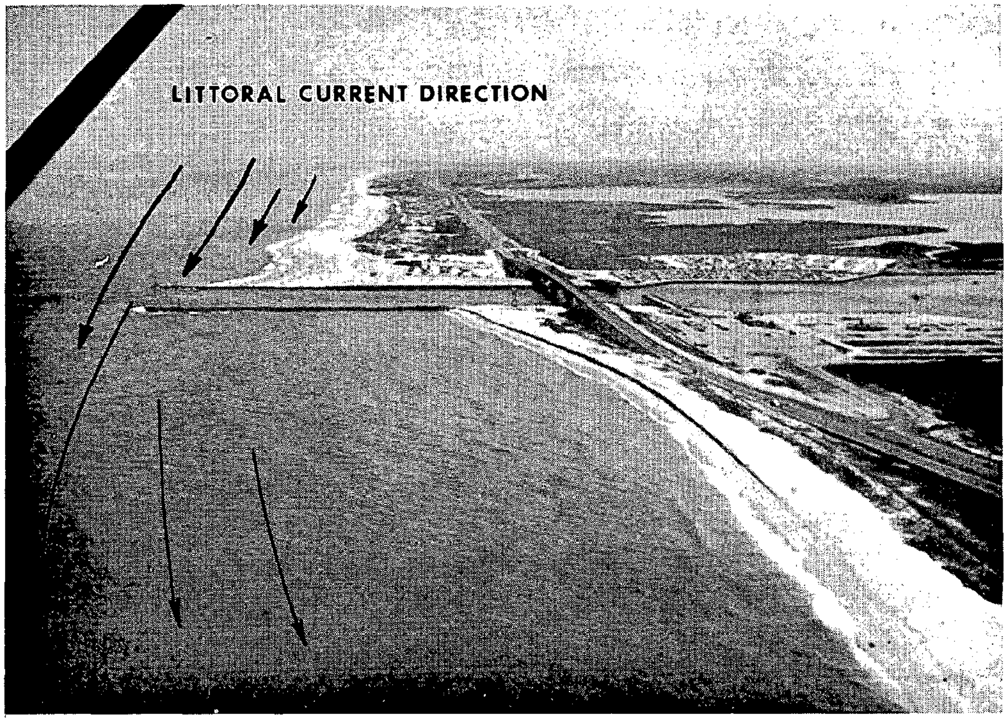


FIGURE 15. Aerial photo of Indian River Inlet showing jetty effect.

FIGURE 16. Aerial photograph of Woodland Beach showing the town situated on a Pleistocene hill isolated from the inland coastal plain by low-lying marshes.

When properly used beach structures have a place in shore protection, but according to the Army Corps of Engineers Coastal Engineering Research Center the best protection is afforded by methods as similar as possible to natural ones.

The Shoreline of Kent County and Northeastern Sussex County

Effects of coastal processes of sea level rise, erosion, and deposition described previously in general terms, are different in the several distinctive segments of the Delaware shoreline. This part of the paper examines the shoreline types found in the area from the Smyrna River to Broadkill Beach and the shoreline change processes affecting this area.

Geologists have classified Delaware's shoreline into six types, two of which occur in the area between the Smyrna River and Broadkill Beach: (1) a broad marsh behind minor, isolated sandy barriers from southeastern New Castle County to Bowers in Kent County, and (2) a broad marsh behind continuous, narrow sandy barriers from Bowers to the vicinity of Roosevelt Inlet at Lewes.

Smyrna River to Bowers

The Delaware Bay shoreline of Kent County to Bowers is a low coastal plain with a topographic relief of less than thirty feet bordered along the Bay shore by minor, isolated sandy barriers and narrow beaches. The pre-Holocene sand and gravel sediments, deposited during times of higher sea levels provide a source of course sediments that form the beaches and sandy barriers along the Delaware Bay shore. Configuration of the present shoreline derives from the topography of these ancient sediments. Ancient drowned river valleys now covered by marshes appear as slight indentations of the shoreline. Highlands of the pre-Holocene[1] sediments account for bulges along the shoreline and are areas of concentrated erosion.

Sandy beaches in Kent County north of Bowers are found only locally in a few places. These washover sand barriers are characterized by poorly sorted sand, gravel and shell material with little silt or clay. Marsh land edges most of the shoreline in Kent County north of Bowers.

Between the Smyrna River and Bombay Hook Point are a series of hummocks of pre-Holocene sedimentary material separated by broad tidal marshes from the inland necks. The marshes occupy depressions filled with 10 to 50 feet of muds deposited millions of years ago. The Smyrna River and nearby creeks drain out of these marshes between the hummocks. At places where the muds are compacting at Smyrna River and Pierson Cove for example, shoreline erosion occurs at a faster rate than along the shorelines of sediments that pre-date the muds such as the Woodland Beach sediments (see Figure 16).

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[1]Holocene is a geologic time period from about 10,000 years ago to the present. Pre-Holocene would be more than 10,000 years ago.

Tidal creeks draining the marshes behind Woodland Beach and Bombay Hook Point carry course sediments from the old hummocks at Woodland Beach and Bombay Hook Point to the Bay shoreline beaches supplying them with sedimentary material. Littoral transport along the Bay shore is toward the south. South of the Smyrna River the Bay estuary is wide enough to permit sufficient sweep of winds to produce waves capable of greater sediment transport and shoreline erosion than occurs to the north. Nevertheless, north of Pickering Beach there is limited littoral drift of sediments as evidenced by the scarcity of sandy beaches.

The shore area from Bombay Hook Point to Pickering Beach is characterized by broad tidal marshes of 20 to 80 foot thick ancient muds drained by Duck Creek, Leipsic River, Simons River, Mahon River and Little Creek. The shoreline has small pockets of sandy beach, but most of it is a mud shoreline. Ancient highlands of sedimentary material are too far inland to supply sufficient material to build extensive barrier beaches. Port Mahon is typical of this shoreline.

At Port Mahon the marsh shoreline has existed for approximately 3,200 years. Since 1845 about one-half mile of shoreline has disappeared due to erosion and submergence. Figure 17 shows the situation in 1973 with the road to Port Mahon washed out and covered by sand and debris from a minor storm NOT a hurricane or severe Northeaster. The concrete blocks in the photo were a temporary means to prevent further erosion of the road at that time. Figure 18 taken in 1975 shows Port Mahon after bulkheading was built to slow down shoreline erosion. Maintenance of this shoreline at its present position will require such measures, costly to build and maintain.

Pickering Beach and Kitts Hummock are located on thin sandy barriers (beaches) with narrow marshes between them and inland highlands of Pleistocene age. Since 1845 the beach face has retreated about one-quarter mile. Less erosion has occurred here than at Port Mahon due to the subsurface sands and gravels compared to the mud subsurface at Port Mahon.

Bowers to Slaughter Beach

The Town of Bowers lies on Murderkill Neck which is flanked to the north and south by the ancient (pre-Holocene) valleys of the St. Jones and Murderkill Rivers, respectively. Beneath Bowers are hard sand and mud sediments indicating that this area was once a shallow sea when the sea level was higher. The upland surface between the two rivers provides sand to the beach and, because of its elevation and more resistant materials it erodes less rapidly than adjacent shorelines at the St. Jones River outlet and at South Bowers. Figure 19 shows this differential erosion.

At South Bowers geologic cross sections indicate that past shorelines consisted of broad marsh lands. About 2,700 years ago the sea level was at least ten feet lower with marsh land extending over a mile farther east than at present.

FIGURE 17. 1973 photograph of the shoreline at Port Mahon showing the road washed out and covered by sand and debris.

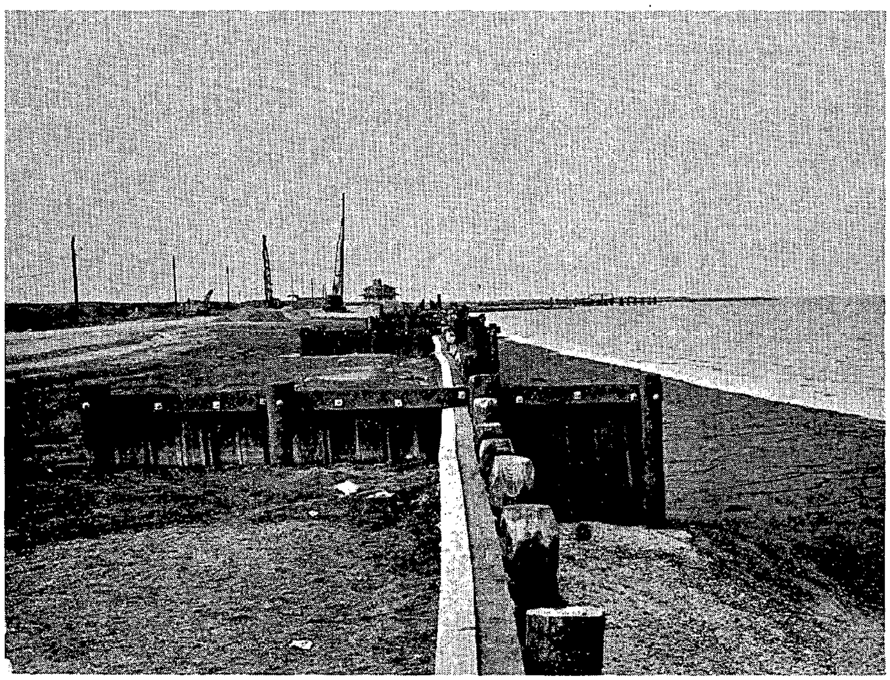

FIGURE 18. A photograph of bulkheads at Port Mahon constructed in 1975 to prevent destruction of the road by storm wave activity. (It should be noted that even portions of this barrier have recently been undermined due to wave action on the unstable mud which the bulkheads pentrated.)

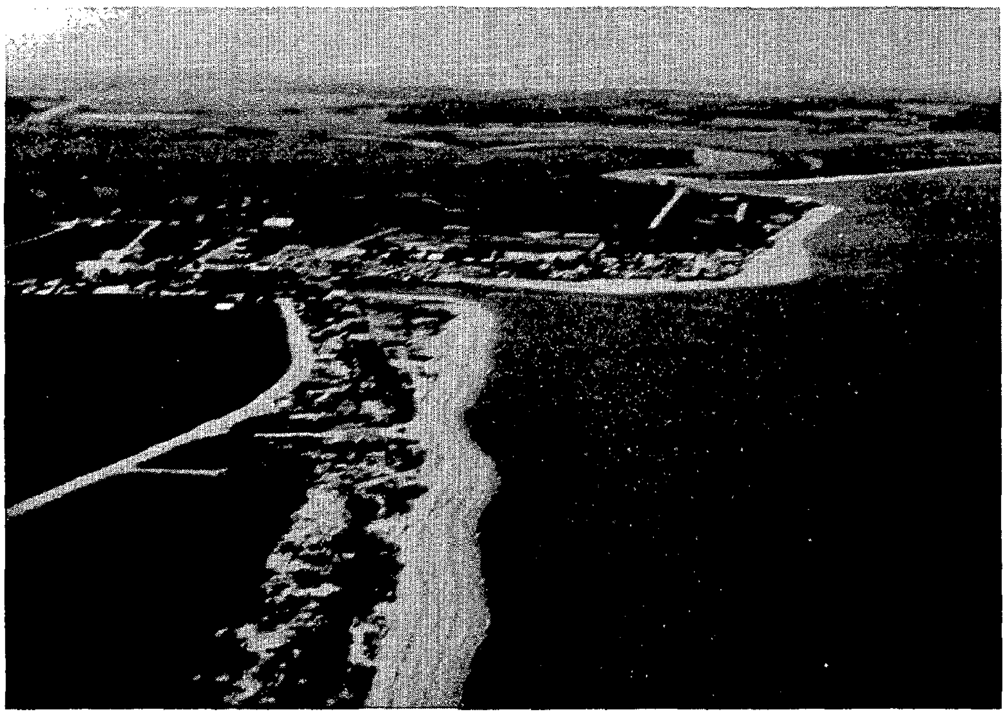

FIGURE 19. Aerial photograph of Bowers and South Bowers looking north. Bowers is situated on a highland between the Murderkill and St. Jones Rivers. The barrier at Bowers is eroding more slowly than the barrier to the south at Bowers Beach which is situated over a deep, pre-Holocene valley now filled with muddy sediments.

Due to more resistance to erosion at Bowers, buildings are less susceptible to undermining than at South Bowers. Pilings of not less than one hundred feet are required for firm building foundations at South Bowers. Considerable erosion control work has been undertaken at South Bowers including placement of an artificial submerged barrier.

At Bowers the shoreline becomes one of continuous sandy barriers (beaches) and broad marshes. Although wave erosion increases here due to the larger fetch of Delaware Bay the sandy barriers are prominent features of the southeastern Kent County and northeastern Sussex County shorelines. This seems due to a larger supply of Pleistocene sand and gravels and greater longshore sediment transport by increased wave energy.

Milford Neck between the Murderkill and Mispillion Rivers has Pleistocene sand and gravels at less than ten feet below the present shoreline with the upland extending to the Bay shoreline in the subsurface, overlain by a thin surface of muds and barrier (beach) sands. This Pleistocene subsurface provides a comparatively firm foundations with little compaction. Landward migration of the shoreline barrier here has been about one-quarter mile over the past 130 years.

Slaughter Beach to Broadkill Beach

The Northern part of Slaughter Beach is underlain by as much as forty feet of soft, compacting muds. Sea level 6,220 years ago was approximately forty-five feet lower than at present and the area of the present sand barrier was covered by marshes.

Central and southern parts of Slaughter Beach are closer to the Pleistocene headland of Slaughter Neck, but the depth to the Pleistocene subsurface level is not yet known.

Rapid erosion is affecting the Slaughter Beach shoreline. Erosion of the Northern part of the beach has been slowed by groins emplaced after the 1962 storm, but the Southern shoreline has only bulkheads to temporarily halt erosion. These bulkheads (shown previously in Figure 13) now stand eight to ten feet above the present shoreline and could be undermined by a major storm. If this occurred, the houses behind the bulkhead would wash away and the shoreline would reform landward of its present position.

From Slaughter Beach to Primehook Beach the shoreline is one of a continuous estuarine washover barrier bordered by broad marshes on the landward side. Pleistocene highlands of Slaughter Neck and Primehook Neck reach within one-quarter mile of the shoreline. At Fowler Beach these Pleistocene sands and gravels form a shallow subsurface approximately five feet below mean low sea level. A broad subtidal flat extends about one mile offshore. Primehook Beach to the south exhibits the same subsurface features.

The shoreline of a continuous estuarine washover barrier with a broad inland marsh continues from Primehook Beach to Broadkill Beach. Holocene muds from ten to sixty feet thick underlie the shoreline sands. At Broadkill Beach there is geological indication that over the last 200 years this area has received a relatively large supply of sand and gravel. The supply came from sediment movement around Cape Henlopen and then along the southern Delaware Bay shoreline. This builtup the barrier beach between Lewes and Broadkill Beach.

Due to its proximity to the Bay mouth the coast at Broadkill Beach is susceptible to greater wave attack (than the beach to the north). Flooding and washover are common problems here. In view of the geologic hazards of washovers and the landward movement of the estuarine barrier (beach) the houses in this area have to be built on piling, which is a short term solution and of no long term value. Groins built along Broadkill Beach give the impression that the beach is growing due to the trapping of sand. However, failure to maintain the groin field will allow the natural erosive process to take over. Also, this measure is only locally effective and is detrimental to areas to the north and south by increasing erosion there.

Littoral Drift and General Shoreline Change

Littoral drift of sediments along the shoreline from Pickering Beach to south of Broadkill Beach as far as Roosevelt Inlet at Lewes is low to moderate. A nodal area exists between Broadkill Beach and Roosevelt Inlet as evidenced by sand accretions on the southeast sides of groins at Slaughter Beach and Broadkill Beach, indicating a northerly littoral movement, and on the northwest side of the jetty at Roosevelt Inlet indicating a southerly movement. The nodal point where the littoral current changes direction varies within this area according to tide, wave and wind conditions.

Rates of shoreline change along Delaware Bay vary considerably from point to point and at different times. In general, over the past century the shore has continuously eroded from one to twenty-five feet per year. The few areas of accretion are localized and in part due to mans' activities. Highest rates of erosion tend to occur where marsh sediments form the shoreline. In areas where more resistant pre-Holocene headlands extend to the coast, such as the more compacted sediments at Bowers, average rates of erosion are significantly less. Most shoreline erosion in Delaware Bay is believed to be caused by waves generated within the Bay by local winds (Weil 1976).